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A REVIEW OF PUBLICATIONS ON THE BIRD/AIRCRAFT STRIKE HAZARD.(U)
JUL 76 A S MOOREHEAD, P R MCCRACKEN

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A REVIEW OF PUBLICATIONS ON THE BIRD/AIRCRAFT STRIKE HAZARD

DIRECTORATE OF ENVIRONICS
TYNDALL AIR FORCE BASE, FLORIDA 32403

JULY 1976

FINAL REPORT: OCTOBER 1975 - JUNE 1976

AIR FORCE CIVIL ENGINEERING CENTER
(AIR FORCE SYSTEMS COMMAND)
TYNDALL AIR FORCE BASE
FLORIDA 32403

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The annual cost to the United States Air Force (USAF) to replace or repair aircraft damaged by bird/aircraft collisions has led to an intensive study of the problems associated with birds or airfields and in the enroute environment. Since 1969 an active program has been in effect, first at the Air Force Weapons Laboratory (AFWL) at Kirtland Air Force Base, New Mexico, and in 1975 at the Air Force Civil Engineering Center (AFCEC), Tyndall Air Force Base, → next page

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Florida. This report reviews those Technical Notes (TNs) and Technical Reports (TRs) that have been published as a result of the program effort.

PREFACE

This project was transferred from the Air Force Weapons Laboratory (AFWL), Kirtland Air Force Base, New Mexico. The report was prepared under project 21033E09 by the Air Force Civil Engineering Center (AFCEC), Tyndall Air Force Base, Florida.

Inclusive dates of research were October 1975 through 30 June 1976. The report was submitted in July 1976 by AFCEC project officer 1st Lieutenant Portia R. McCracken, Environmental Planning Division.

Acknowledgment is made to those researchers whose work has been abstracted in this report with little or no notification. They are dedicated representatives in the effort to reduce bird/aircraft strike hazards in the United States Air Force.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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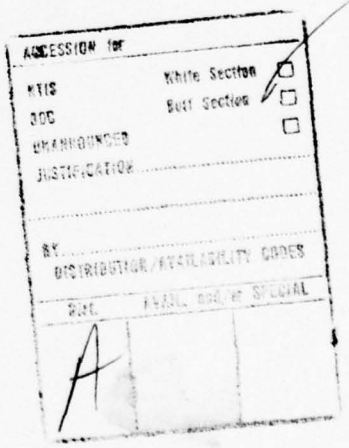

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SECTION I

INTRODUCTION

A research and development program of the Air Force Bird/Aircraft Strike Hazard problem was established at the Air Force Weapons Laboratory (AFWL), Kirtland Air Force Base, New Mexico in 1969. Initially, most of the emphasis was placed on controlling birds in the airport environment. The program further evolved into research and development efforts for both the airdrome and enroute problem. Considerable progress was made through research efforts in reducing bird/aircraft hazards.

Numerous technical notes (TNs), technical reports (TRs), and technical papers given at conferences and other professional gatherings have been published with regard to this Air Force problem. The abstracts of these reports are for use as an aide to both military and commercial airports with bird strike problems. This TR is divided into sections and is designed to provide easy access for those whose interest lies along these particular lines. This TR is a sequel to AFWL-TR-74-11, March 1974, A Review of Publications on The Bird/Aircraft Strike Hazard by Claude L. Scott, Alc, USAF, and Rutherford C. Wooten, Capt, USAF.

SECTION II

AIRDROME AND ENROUTE PROBLEMS

1. BIOACOUSTICS

Boudreau, Gordon W.

Report of Bio-Acoustics Tests at Holloman Air Force Base, New Mexico, AFWL-TN-71-006, Air Force Weapons Laboratory, Kirtland AFB NM, March 1971.

This study was made to evaluate the effectiveness of bioacoustics in dispersing Horned Larks (*Eremophila alpestris*) and House Finches (*Carpodacus mexicanus*) from the immediate vicinity of the rocket sled test track at Holloman Air Force Base, New Mexico.

Bioacoustics involves the use of recorded animal sounds, projected at target species to influence their behavior. In this case, the natural alarm sounds of Horned Larks and House Finches were used. Conclusions drawn from this study indicate that the use and proper application of bioacoustics will reduce the risk of rocket sled and Horned Lark/House Finch collisions to tolerable levels (about 5 in 100).

Boudreau, Gordon W.

Report of Bio-Acoustics Test at Charleston Air Force Base, South Carolina, Air Force Weapons Laboratory, Kirtland AFB NM, January 1971.

This study involved bioacoustics tests to evaluate the effectiveness of Herring Gull (*Larus argentatus*) distress calls to disperse and repel both Herring Gulls and Ring-billed Gulls (*Larus delawarensis*) from the airfield at Charleston Air Force Base SC. These gulls frequented the runways and taxiways of the air field, constituting a serious hazard to arriving and departing military and commercial aircraft.

This study comprised daily observations and tests from 1400 hours, 22 January 1971 through 1000 hours, 26 January 1971, with gull activity commencing shortly after dawn and being suspended after the gulls left for their night roost. The result of the tests indicates the two species of gulls mentioned above respond well to projections of the alarm sound of the Herring Gull by evacuating the area.

Kolz, A. Lawrence and Richard Johnson.

Frequency Response Measurements for Cassette Tape Players, AFWL-TR-74-147, Air Force Weapons Laboratory, Kirtland Air Force Base NM, October 1974.

Automotive cassette tape players made by 21 companies were surveyed to determine a prototype unit that may be used as part of a mobile bird dispersal system to help reduce the USAF bird/aircraft strike hazard. Nine units were selected on the basis of the manufacturer's specifications and tested for frequency response. The three with the flattest measured responses were then used to record audio sonograms from taped recordings of four bird distress calls. These tests indicated that, of the nine players, the three exhibiting the flattest frequency response were the Hitachi Model CS-200, Pioneer Model KP-300, and Realistic catalog no. 12-1823.

Beason, Robert

A Radar and Direct Visual Study of the Hazard to Aircraft from Bird Migrations in the Southwest, AFWL-TR-74-175, Air Force Weapons Laboratory, Kirtland AFB NM, March 1975.

The increasing number of aircraft accidents caused by bird strikes while in-flight is a concern of the Air Force. This report concentrates on the danger during low-altitude, high-speed missions as well as takeoffs and langings at a fixed base. Methods for obtaining data are discussed with results from locations throughout the U.S. and the data are presented to show the concentrated areas where birds migrate. Recommendations are made for a continuing study and methods for supplying flight-plan information that would avoid concentrated bird areas.

Hubbard, Joel and Warren Flock

Radar Observation of Migratory Waterfowl at Cold Bay, Alaska, AFWL-DE-TN-74-08, Air Force Weapons Laboratory, Kirtland Air Force Base NM, May 1974.

Extensive bird migrations in Alaska and between Alaska and the Pacific Northwest pose a hazard to USAF air operations. Using Aircraft Control and Warning (AC&W) radars operated by the Alaskan Air Command at Cold Bay and Cape Newenham, and FAA radar facilities at Anchorage and Seattle, it was planned to monitor the fall migration of waterfowl in an effort to provide information about the movements of birds from Alaska to the contiguous United States relative to the bird/aircraft strike hazards (predictability and real time analysis). This note describes radar observations of migratory waterfowl near Cold Bay, Alaska from 12 October to 13 November 1973.

2. DETECTION, AVOIDANCE, BIRD MIGRATION

Gauthreaux, Sidney

The Observation of Birds with Weather and Airport Surveillance Radars, AFWL-TR-74-57, Air Force Weapons Laboratory, Kirtland Air Force Base NM, April 1974.

The use of radar to detect and monitor weather phenomena and radar's vital role in the detection and control of aircraft are well known, but relatively few radar technicians and operators realize the importance of radar for studies of bird, bat, and insect movements in the atmosphere. In this paper the application of radar to detect, quantify and monitor the movements of birds is emphasized. Of all the approaches currently being used to reduce the hazards that birds pose to aviation, radar techniques offer promise of definite results. Furthermore, the distribution of surveillance radars at numerous locations throughout the United States, particularly in the vicinity of active airfields, adds greatly to the attractiveness of this approach.

The review of radar techniques and bird migration information in this report should greatly aid radar operators in recognizing the various types of echoes from

birds displayed on weather and air traffic control radars, in estimating the numbers of birds passing overhead, and in gathering information on the altitude of the birds aloft. Use of these techniques should greatly benefit aviation interests, both civilian and military, by reducing the number of bird/aircraft collisions and improving flight safety.

Beason, Robert

A Review of the Influence of Weather on Bird Migration, AFWL-TR-74-196, Air Force Weapons Laboratory, Kirtland Air Force Base NM, March 1975.

This literature review updates the work of Lack in 1960 on weather and passerine migration. Noted additions include data obtained with radar surveillance, or tracking of birds, as well as waterfowl, shorebird, and raptor migration. All orientation research utilizing caged migrants has been omitted. Only research on free-flying birds is included. Although the internal physiology of the bird is important in the limitation and continuation of migration, it has been disregarded. The influence of weather on bird migration is essential to predicting bird/aircraft strike hazards, thus enabling avoidance of the hazards and the enhancement of flight safety.

Beason, Robert

A Seasonal Occurrence Checklist of Waterfowl Hazardous to Flight Safety in the Southwestern United States, AFWL-TR-74-174, Air Force Weapons Laboratory, Kirtland Air Force Base NM, March 1975.

Large numbers of overwintering and migratory waterfowl present a serious hazard to USAF low-level training missions in the southwestern US. Waterfowl census data from several National Wildlife Refuges in the southwest have been compiled and summarized in occurrence checklists. Comparison of refuge data with the proposed low-level training mission will enable one to assess the potential bird/aircraft strike hazard and determine possible adjustments in flight scheduling and/or alternate areas to reduce the hazard.

Meyer, George

The Application of Probability Calculations for Bird-Aircraft Strike Analyses and Predictions Using Radar, AFWL-TR-74-145, Air Force Weapons Laboratory, Kirtland Air Force Base NM, March 1975.

A theoretical development is given for the calculation of binomial probability distribution functions using radar for assessing the risk of bird hazards to aircraft. A set of airspace cells is defined by beam geometry, pulse width, and a given aircraft flight path, each with a determined number of birds. Each distribution function can be studied to determine the maximum risk and corresponding number of birds involved. The cumulative probability of bird strikes over an entire route can be determined by calculating the union of discrete cell probability sets.

Bystrak, Danny

Wintering Areas of Bird Species Hazardous to USAF Aircraft, AFWL-TR-74-217, Air Force Weapons Laboratory, Kirtland Air Force Base NM, April 1975.

Maps showing the winter distribution and relative abundance of 144 species of North American birds were prepared from counts made during the National Audubon Society's annual Christmas Bird Count. The total number of persons participating in the 1972-73 count was 20,373. Since the intensity of coverage on the nearly 1000 counting areas varies, each count was divided by the number of party-days of coverage for that particular area. A party-day is defined as 10 hours of observation by a single observer working alone or by a party of observers working together within close contact. Although the raw data from the Audubon Christmas Bird Count have been published for 73 consecutive years, this is the first time this information has been prepared in map form for a large number of species. The species selected for mapping are members of those bird families that are considered the greatest potential threat to low-level aircraft operations within the continental United States. The discussion accompanying the maps summarizes the potential hazard to aircraft of the various species with relation to concentration areas, time of year, time of day, and geographical features. The maps tend to be more accurate in the east because of the greatest number of counts. The west was largely subject to the individual mapper's interpretation of the data, since there are large areas with no counts in them.

3. FALCONRY

Mattingly, Edwin

Falconry as a Means of Reducing Bird-Aircraft Strike Hazards at Whiteman Air Force Base MO, AFWL-TR-73-175, Air Force Weapons Laboratory, Kirtland Air Force Base NM, January 1974.

A serious bird/aircraft strike hazard exists at Whiteman Air Force Base (WAFB) MO, because of the resident flock of protected Greater Prairie Chickens (*Tympanuchus cupido*) which may be found on and near the runways. In recent years an increasing traffic load involving mostly jet aircraft, frequently with highly sensitive cargo, has raised the strike hazard to intolerable limits. During the last 5 years, a minimum of 12 bird/aircraft strikes were recorded each spring. After almost all conventional methods of bird control had been tried with only partial or temporary success, a program of continual harassment using combinations of men, dogs, and falconry proved the most effective in the spring of 1973. Two airstrikes were experienced early in the test program and none after that. By techniques described herein, the strike hazard at WAFB was reduced by at least 83.3 percent.

4. BIRD/AIRCRAFT STRIKE HAZARD (BASH) SURVEYS

Beason, Robert C. and John P. Nemergut.

Bird-Strike Hazard at the John F. Kennedy Space Center Runway, AFWL-TR-74-111, Air Force Weapons Laboratory, Kirtland Air Force Base NM, July 1974.

An evaluation of the hazards birds pose to the orbiter on its return to earth and to conventional aircraft as parts of the NASA Space Shuttle program was conducted at the request of NASA/SP by the Air Force Weapons Laboratory personnel. The landing speed of the orbiter, the weight requirement precluding a thicker orbiter skin and the abundance of avian species at the Kennedy Space Center are the main factors contributing to the bird/strike hazard potential. Recommendations as means of reducing the potential hazards are presented.

Nemergut, John P., R. C. Wooten, Jr. and Robert O. Collum.

Evaluation of the Bird-Aircraft Strike Hazards at Seymour Johnson Air Force Base NC, AFWL-TR-75-161, Air Force Weapons Laboratory, Kirtland Air Force Base NM, March 1976.

A serious bird/aircraft strike hazard potential exists at Seymour Johnson Air Force Base, North Carolina. The three problem areas involve flying routes to and at the Dare County Gunnery Range, the base airdrome, and birds roosting in fixed facilities adjacent to the runways. Five National Wildlife Refuges in the area surrounding the gunnery range provide suitable habitat for waterfowl, shorebirds, and seabirds. Population estimates of 750,000 to 3 million overwintering Starlings, blackbirds, and grackles indicate that birds roosting approximately 4.3 miles north of the airfield pose a potential airdrome hazard. In addition to these overwintering birds in the area, pigeons, sparrows, and Starlings are roosting and nesting in fixed facilities adjacent to the runway. Waterfowl also concentrate on sewage lagoon ponds at the west end of the runway. Effective avoidance of bird activity for routes to the range and control of hazardous species on the airfield environment will require a persistent and coordinated effort. Measures to reduce the hazard potential include (1) determination and avoidance of airspace of known concentrations of waterfowl, shorebird, and seabird activity, (2) reducing the attractiveness of environmental features in the airbase environment, (3) population reductions within the fixed facilities, and (4) dispersal of Starlings from the airfield using Starling distress calls.

de Boer, Jelle, George Meyer and Edwin Mattingly.

Combined Bird Control Techniques and Analysis Relative to Bird-Aircraft Strike Hazard, AFWL-TR-74-323, Air Force Weapons Laboratory, Kirtland Air Force Base NM, April 1975.

All US Air Force bases have a potential for bird/aircraft strike hazards. The seriousness of such a hazard is dependent on the following criteria existing in each specific airdrome environment, either singularly or in combinations:

1. Number and/or size of birds in the environment.

2. Time (day, month, season, or year).

3. Airdrome operation (mission).

4. Control techniques enforced (direct or indirect).

This technical report addresses problems encountered on four USAF bases (Hill AFB UT, Moody AFB GA, Vance AFB OK, and Whiteman AFB MO), the recommendations made for direct control techniques and the results obtained at some of these bases. The report stresses the importance of specificity associated with each Air Force operational problem involving bird hazards.

Nemergut, John P. and R. C. Wooten, Jr.

An Evaluation of the Bird-Aircraft Strike Hazard at the Hughes Airport, Culver City, CA, AFWL-DE-TN-74-011, Air Force Weapons Laboratory, Kirtland AFB NM, April 1975.

The bird/aircraft strike hazard at the Hughes Airport, Culver City, California, appears to involve principally those species attracted to habitats which man can effectively control. The primary habitats and hazardous species observed during this survey include intermittent water impoundments with gulls, ducks, and shorebirds; short grass with Starlings, pigeons, and Horned Larks; and tall grass with swallows and meadowlarks. Gulls, Starlings, pigeons, and Horned Larks presented the greatest hazard potential due to their numbers and flocking behavior. Recommended control measures include (1) maintaining the grass length at 8 to 10 inches, (2) mowing the grass during one period, (3) eliminating the intermittent water impoundments, and (4) using a bioacoustic system to disperse gulls and Starlings.

Mattingly, Edwin and Robert Collum.

Preliminary Evaluations of Bird-Aircraft Strike Hazard at Moody AFB, Georgia, AFWL-TN-74-003, Air Force Weapons Laboratory, Kirtland AFB NM, March 1974.

A complex bird/aircraft strike hazard has existed at Moody AFB, with Cattle Egrets, crows, blackbirds, and vultures being distinct hazards. It shows clearly that

strikes occurred during each month of the year but were most numerous during the winter. Analysis of the data shows that vulture strikes occurred during early afternoon of the summer months at altitudes of approximately 1000 feet. Blackbird strikes occurred during early morning or evening hours during the winter months and at low altitudes, while known egret strikes were recorded in the morning at low altitudes. Some recommendations are as follows:

1. The use of shell crackers for the removal of crows and Cattle Egrets.

2. The removal of the sanitary landfill area to alleviate the crow problem.

3. Curtailment of flight activity at dawn and dusk to avoid the periods of blackbird movement.

4. Erection of a sound barrier to deflect the flocks around the base.

Stout, John F., W. H. Gillet, J. L. Hayward, Jr., and C. L. Amlane, Jr.

Dispersal of Seagulls in an Airdrome Environment, AFWL-DE-TR-74-324, Air Force Weapons Laboratory, Kirtland AFB NM, June 1975.

Glaucous-winged Gulls (*Larus glaucescens*) provide an acute bird/aircraft hazard at Shemya Air Force Base, Shemya Island, Alaska. The problem was evaluated by making survey counts of aggregations of gulls on the island. At Ellington Air Force Base, Texas, Ring-billed Gulls (*Larus delawarensis*) often aggregate in large groups on or near the active runways and are hazardous to aircraft. A sanitary landfill located close to the base was found to attract gulls to the area. Recorded gull calls played to aggregations of Glaucous-winged Gulls at Shemya Air Force Base showed that the distress call, more than any other call, resulted in fewer birds remaining following playback. Distress calls played back to aggregations of Ring-billed Gulls near Ellington Air Force Base were also effective in dispersal. A preliminary experiment with taxidermally-mounted model gulls at Shemya Air Force Base indicated that gull models might be effective in permanent dispersal of gulls from critical areas. Further work with models

at Ellington Air Force Base showed that model gulls placed on their sides or models mounted with outstretched wings were effective in the dispersal of gulls from the areas of aggregation. Further studies completed at Whidbey Island, NAS, Oak Harbor, Washington, proved effective when using artificial models made from fiberglass. The effectiveness of sound and artificial model gulls was evaluated in a breeding colony and a non-breeding colony.

SECTION III

PROCEEDINGS, SPECIAL REPORTS, CONFERENCES

1. THE BASH PROGRAM

de Boer, Jelle.

The United States Air Force Bird/Aircraft Strike Hazard (BASH) Program, A Conference on Biological Aspects of the Bird/Aircraft Collision Problem, February 5 to 7, 1974, pp. 125-148.

The USAF BASH Program was established in 1969 with a one-man program and a small operating budget. Its objective was to assess techniques for controlling birds in the airport environment. The formal research and development program began in 1970 with an investigation of the ecological factors influencing the gull-aircraft hazards at Charleston Air Force Base. During this study the applicability of short-range radar was investigated.

Since that date the program has been expanded to an eight-man staff, including three PhDs and an annual operating budget of several hundred thousand dollars in support of individual research and development projects. Twenty-five technical notes and reports have been published and numerous consultations have been made with regard to bird control at various Air Force installations.

The BASH Program is conducted by the Civil Engineering Research Division of the Air Force Weapons Laboratory, and research is accomplished through contractual and in-house efforts. Of the latter, the base surveys and base consultations on bird problems have received considerable emphasis. These involve applying known techniques and researching others which can be brought to bear on any given problem in this area.

The BASH Program is divided into two separate and distinct problem areas. One involves bird strike hazards for the airdrome, and the other is associated with bird problems enroute. Both demand equal emphasis. Major techniques involving detection, avoidance, and harassment of birds are discussed.

Nemergut, John P.

A Review of the Bird Strike Problem, Conference on Transparent Aircraft Enclosures, AFWL-TR-73-126, June 1973, pp. 423-445.

The bird hazard to aircraft is a significant problem which emphasizes the need to share, rather than compete for, airspace. The conditions most conducive to a serious aircraft strike are either transport aircraft taking off during daylight hours at a coastal base, or trainer aircraft travelling in excess of 280 knots on a training mission below 2000 feet AGL during October in the southwestern United States.

The problem of birds and aircraft must be looked at as multidisciplinary, drawing on the necessary expertise in biology, environmental sciences, and engineering.

The problem can be divided into airdrome and enroute hazards. Biological control must be effected to reduce the bird concentrations around the airdrome. Habitat management offers the most promise by reducing those environmental features which attract birds. Birds may be found in the airdrome for any one or all of the following reasons: water, food, shelter, safety, movement routes, and nesting. Through sound habitat management, birds will no longer be attracted to the airdrome environment. Acoustical and other scare devices may effect short-term avoidance responses. However, habituation to the stimulus becomes the problem if the environmental attractants are not concurrently eliminated. Close-in surveillance radar is a second palliative measure; for example, pilots can be warned of bird concentrations on the runway and delay takeoff. The least effective means of controlling birds is attempting to kill them. Again, this is so because the environmental attractants will draw other birds into the area. Then one must ultimately kill all the birds to effect kill control, which is unacceptable. The strike potential to enroute aircraft can be effectively reduced by radar detection and subsequent avoidance of bird concentrations, i.e., bird forecasting, by scheduling aircraft operations to avoid peak periods of the hazard and through development of on-board aircraft devices (perhaps strobes) to alert birds of approaching aircraft. The extent of damage can be reduced through aircraft hardening.

A reevaluation of the materials criteria and standards is necessary, as is the development of materials capable of withstanding higher impact forces.

2. B-1 ASSESSMENT

Compton, Dennis E., John P. Nemergut, and Keith R. Newsom.

B-1 ASSESSMENT, AFWL-TR-75-160, Air Force Weapons Laboratory, Kirtland AFB NM, July 1975.

Bird-aircraft collisions have become a significant problem since the development of high-speed aircraft and the increase in low-level flying missions. When comparing aircraft with similar flying missions, one might anticipate potential bird problems with the B-1 bomber. A literature review revealed that the loon, albatross, pelican, cormorant, waterfowl, and gull families appear to present the greatest hazard to flight test operations on the California coast from San Francisco to Los Angeles. Birds can be expected to appear within the flight test area throughout the year. During the migratory seasons from about March through May and September through November, millions of birds migrate off and along the California coast, presenting the most serious bird hazard. Test flights below 15,000 feet AGL should be limited as much as possible during the migratory season. Coastal radars should be used to determine the areas and intensity of bird activity on a real time basis. Contact should be established with state and federal wildlife agencies to obtain the status and distribution of hazardous local and migratory species.

3. BAT STRIKE

Ireland, Leonard

Reduction of the Bat Hazard to Randolph AFB Aircraft, AFWL/AFOSR-TR-75-146, 10 July 1973 - 10 January 1975.

During the months of April through October, Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) are a major cause of T-38 aircraft engine failures at Randolph AFB, Texas. From 1966 through 1974, 81 T-38 engines were damaged by bats. The majority of engines were lost after sunset, during nighttime training operations. Engines were also damaged during the late afternoon and in the early morning.

The airborne behavior of *Tadarida brasiliensis mexicana* emerging from and returning to the Bracken cave near Randolph AFB was observed with both search and height-finding radars. Radar echoes from dense groups of bats covered areas as large as 1500 km^2 and rose to altitudes of over 3000 m. Evening bat flights appeared to have three distinct phases of development: exit from the roost and ascent, transition to level flight, and dispersal. In the dispersal phase, the bats usually traveled directly toward Randolph Air Force Base. Bat flights may be grouped into three types on the basis of their vertical distribution. One type, characterized by flight at low altitudes, is usually observed on nights when engines are damaged.

A bat avoidance program, based on real time radar observations, was initiated at Randolph Air Force Base during the summer of 1971 and continued through 1974. Since the start of the program, the frequency of engine damage has decreased. It appears possible to predict nights when bat strikes are most likely to occur 24 hours in advance. Strobe lights were found to be an ineffective bat deterrent.

4. BIRD CONTROL

Meyer, G. C. and M. J. Boulter

Bird Control at the Airport, Astronautics and Aeronautics, December 1973.

Bird control at the airport has become a significant problem. An increasing incidence of collisions between aircraft and birds stimulated the United States Air Force to undertake an intensive research program, aimed at controlling birds within the airport environment. Bird-aircraft collisions are a worldwide problem, and damages to aircraft from bird collisions have averaged well over $10 million. More bird-strikes occur during takeoff and landing than any other phase of flight.

Falcons and hawks under the control of trained falconers have been used at European airports to scare birds, and the Air Force has employed this technique at Torrejon Air Base, Spain.

Robbins, Chandler S.

Distribution and Density of Bird Species Hazardous to Aircraft, A Conference on Biological Aspects of the Bird/Aircraft Collision Problem, February 5-7 1974, pp. 191-207.

The Breeding Bird Survey, sponsored by the US Bureau of Sport Fisheries and Wildlife and the Canadian Wildlife Service, involves 2000 randomly distributed roadside counts that are conducted during the height of the breeding season in all US states and Canadian provinces. Observations of approximately 1.4 million birds per year are entered on magnetic tape and subsequently used both for statistical analysis of population trends and for computer mapping of distribution and abundance.

The National Audubon Society's Christmas Bird Count is conducted in about 1000 circles, each 15 miles (24 km) in diameter, in the latter half of December. Raw data for past years have been published in voluminous reports, but not in a form for ready analysis. Under a contract between the US Air Force and The US Bureau of Sport Fisheries and Wildlife (in cooperation with the National Audubon Society), preliminary maps showing distribution and abundance of selected species that are potential hazards to aircraft are presently being mapped and prepared for publication.

5. GULL REPORTS

Stout, John F., James L. Hayward, Jr., and W. Humphrey Gillett

Aggregations of Gulls (Laridae) on Aerodromes and Behavioral Techniques, A Conference on Biological Aspects of the Bird-Aircraft Collision Problem, February 5-7 1974, pp. 125-148.

Glaucous-winged Gulls (*Larus glaucescens*) provide an acute bird/aircraft hazard at Shemya Air Force Base, Shemya Island, Alaska. The problem was evaluated by making survey counts of aggregations of gulls on the island. Aggregations were most common along the north coast, or what was usually the leeward side, of the island. When minus tides were experienced, larger numbers of gulls were usually found along the south coast. Apparently, wind direction had a major influence on the distribution

of the gulls, until low tides made food readily available on the windward (south) side of the island. In addition to coastal areas, gulls were usually found loafing on the runways, drinking and washing at a small lake, and loafing or feeding at the island's garbage dump.

Recorded gull calls played to aggregations of Glaucous-winged Gulls at Shemya Air Force Base showed that the distress call, more than any other call, resulted in fewer birds remaining following playback. The alarm call was the next most effective in this respect, followed by new, choke, and trumpet, respectively. Gulls in natural environments were more resistant to dispersal and returned more frequently than gulls on runways, following playback of calls.

A preliminary experiment with taxidermally mounted model gulls at Shemya Air Force Base indicated that gull models might be effective in the permanent dispersal of gulls from critical areas. Further work with models at Ellington Air Force Base showed that model gulls placed on their sides or models mounted with outstretched wings were effective in the dispersal of gulls from areas of aggregation. In one experiment, models placed on their sides were effective in the dispersal of gulls for a period of 8 days. Model improvements and additional experiments with models are being developed.

Forsythe, Dennis M.

Gulls, Solid Waste Disposal, and the Bird-Aircraft Strike Hazard, A Conference on Biological Aspects of the Bird/Aircraft Collision Problem, February 5-7, 1974, pp. 17-25.

This is a review of gull behavior and ecology at solid waste disposal sites as it relates to the bird-aircraft strike hazard. Emphasis is placed on the 1971-1972 Charleston, South Carolina, study. In North America and western Europe, about six species of gulls commonly frequent refuse disposal sites. The number and occurrence vary with season and geographic region but usually consist of a high proportion of immature birds. Gull activities and movements related to refuse disposal sites are described. Factors which influence the attractiveness of sites for gulls include: disposal techniques, location, presence of

loafing areas and water, and lack of disturbance. Applications of information on gull ecology at disposal sites to reduce the strike hazard and future research goals and needs are discussed.

6. DETECTION, AVOIDANCE, MIGRATION

Flock, Warren L.

Flight Safety Aspects of Precision Radar Near Air Bases, AFML-TR-73-126, Conference on Transparent Aircraft Enclosures, June 1973, pp. 309-317.

The ability of radar to detect birds is now well established. Long-range surveillance radars can detect birds to ranges of 50 nautical miles or more, depending on conditions, and can warn aircraft of bird concentrations. Such radars, however, can generally not detect targets in the near vicinity (within 2 or 3 nautical miles) of the radar. For this purpose, radars employing short pulses and having short receiver recovery times can be applied. The utility of either type of radar for providing warning of birds would be enhanced by the ability to (1) quickly and unambiguously identify targets as birds, and (2) provide information about numbers and types of birds. Identification can be accomplished by use of amplitude and/or doppler frequency signatures of bird echoes, which can be analyzed in real time with Fast Fourier Transform techniques. It appears that the doppler signatures may also be audibly identifiable in some cases by the use of headphones.

A fairly considerable amount of amplitude-signature data has already been accumulated in England. A limited number of doppler signatures have been obtained at Boulder, Colorado, and work is proceeding there on a pulse-doppler radar which will be used to obtain additional signatures. Pulsed noncoherent surveillance radars can be used to obtain amplitude signatures. Coherent pulsed radars (pulse-doppler radars) or continuous-wave radars are needed to obtain doppler signatures. Automatic tracking capability may be highly advantageous for signature purposes. However, for gathering signature data originally in a location where birds are plentiful, it may be satisfactory to simply point the antenna in a fixed direction and let birds fly through the beam.

Green, John L. and Ben B. Balsley.

Identification of Flying Birds Using a Doppler Radar, A Conference on the Biological Aspects of the Bird/ Aircraft Collision Problem, February 5-7, 1974, pp. 491-508.

The Doppler Radar Technique, which has been used successfully in other scientific disciplines, is applied to the study of flying birds. The technique involves a determination of the properties of a "zero-beat" microwave radar signal returned from one or more birds in flight. This "zero-beat" signal is obtained by electronically comparing the transmitted frequency with the frequency (or frequencies) contained in the echo. This doppler signature of birds contains, among other things, information on the (1) mean radial velocity, (2) variable velocities of the wing segments, and (3) wing beat rate. Preliminary results indicate that refined features of the above parameters can be extracted successfully from the echoes by digital spectral analysis. Other methods of analyzing the doppler returns are also examined and discussed. The results demonstrate the efficacy of the technique for identifying various types of birds in flight, and may be useful in airport bird hazard studies, in studies of bird migration patterns, as well as in studies related to bird-flight physics.

Flock, Warren

Radar Studies of Bird Movements in Alaska and The Arctic. A Conference on Biological Aspects of the Bird/ Aircraft Collision Problem, February 5-7 1974, pp. 409-420.

Data taken at three Aircraft Control and Warning (ACW) radar sites in Alaska and nine Detection Early Warning (DEW) radar sites in Arctic Alaska and Canada demonstrate these radars are suitable for monitoring the impressive bird migrations which are a feature of these regions. Large numbers of eiders, geese, and shorebirds migrate along the Arctic coast of Alaska. Sandhill Cranes, Snow Geese, and others migrate between Alaska and Siberia. The Yukon-Kuskokwim delta and Yukon flats are major waterfowl breeding areas of North America. Essentially the entire population of Black Brant congregates in the Cold Bay, Alaska area in the spring and fall before departing en masse.

Most of the birds mentioned, except the eiders, migrate between the northern regions and the lower 48 states of the United States and thus contribute to the hazard of collisions between birds and aircraft in the lower 48 states and Canada. Considerable aircraft traffic also takes place in Alaska and the Arctic itself, and the amount of aircraft activity can be expected to increase as work proceeds on the Alaska pipeline and prospecting for oil in other Arctic regions. The ACW and DEW radars provide a capability for environmental monitoring throughout much of Alaska, but no suitable radar is yet available in the important area near the south end of the Alaska pipeline.

Gauthreaux, S. A., Jr.

Quantification of Bird Echoes on Airport Surveillance Radar, AFML-TR-73-126, Conference on Transparent Aircraft Enclosures, June 1973, pp. 517-530.

Radar has become an important tool for bird migration studies (Eastwood, Radar Ornithology, Methuen and Co., Ltd., London, 1967), but estimating bird densities from echo densities on the radar screen has often been difficult if not impossible. In this paper, the use of the US Weather Bureau's WSR-57 radar for quantitative studies of nocturnal bird migration is reported first. Emphasis is on (1) the direct visual quantification of bird densities aloft using a telescope directed at the moon on cloudless nights during full moon periods, or pointed up an intense light beam on nights when the moon was not available, and (2) the relationship between the density of birds aloft and the signal strengths of the echoes as measured by the radar's stepped attenuator. The results indicate that the WSR-57 can often be used successfully to estimate the number of birds aloft in much the same manner as rainfall intensity is measured by meteorologists using radar. Because of the pulse volume (4.0μ/sec) and the recovery time of the WSR-57, it cannot provide detailed information on bird densities and distributions at ranges within 6 nautical miles.

During 1972, the ASR-4 radar operated by the Federal Aviation Agency was evaluated as a means of providing detailed information on bird movements in the immediate vicinity (within 6 nautical miles) of airports. Preliminary results of research on the quantification of bird

movements displayed on the ASR-4 will be presented. The quantification procedure followed was similar to that used to quantify the bird densities displayed on the WSR-57 radar. (Research supported by grant 71-1974B from the Air Force Office of Scientific Research).

Flock, Warren L.

The Identification of Birds by Radar, A Conference on the Biological Aspects of the Bird/Aircraft Collision problem, February 5-7, 1974, pp. 429-442.

Most conventional surveillance radars can detect birds readily (at distances determined by transmitter power, antenna gain, and receiver sensitivity) but are limited in their ability to identify birds. The recording of amplitude and/or doppler signatures, however, allows identification as to type and size, and possibly species, under favorable conditions. Amplitude-signature data taken at Boulder indicate that such identification may be possible not only for single isolated birds but also in the case that echoes are received simultaneously from numbers of birds. The determination of the spectra of the signatures is helpful and may be essential in interpreting amplitude signatures.

Simple low-power pulse radars and continuous-wave (CW) radars, including some portable systems, are suitable for certain signature applications. Pulse doppler coherent radars are valuable research tools and provide additional information beyond that contained in amplitude signatures. The combination of a surveillance radar and a signature radar is ideal for monitoring bird hazards and studying bird migration.

Beason, Robert C.

Aspects of Precision Radar in Monitoring Bird Behavior, 1972 Wilson Ornithological Society Meeting, 11 May 1972.

The purpose of the paper is to introduce a relatively ignored type of radar for use in bird studies. The radar is a small unit which was designed as a marine precision navigational radar. It usually separates in the 3-cm band, has a narrow horizontal beam width and has a peak power of 25 kw or less. This type of radar is designed to detect birds sitting on the runway and those flying into the traffic pattern.

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